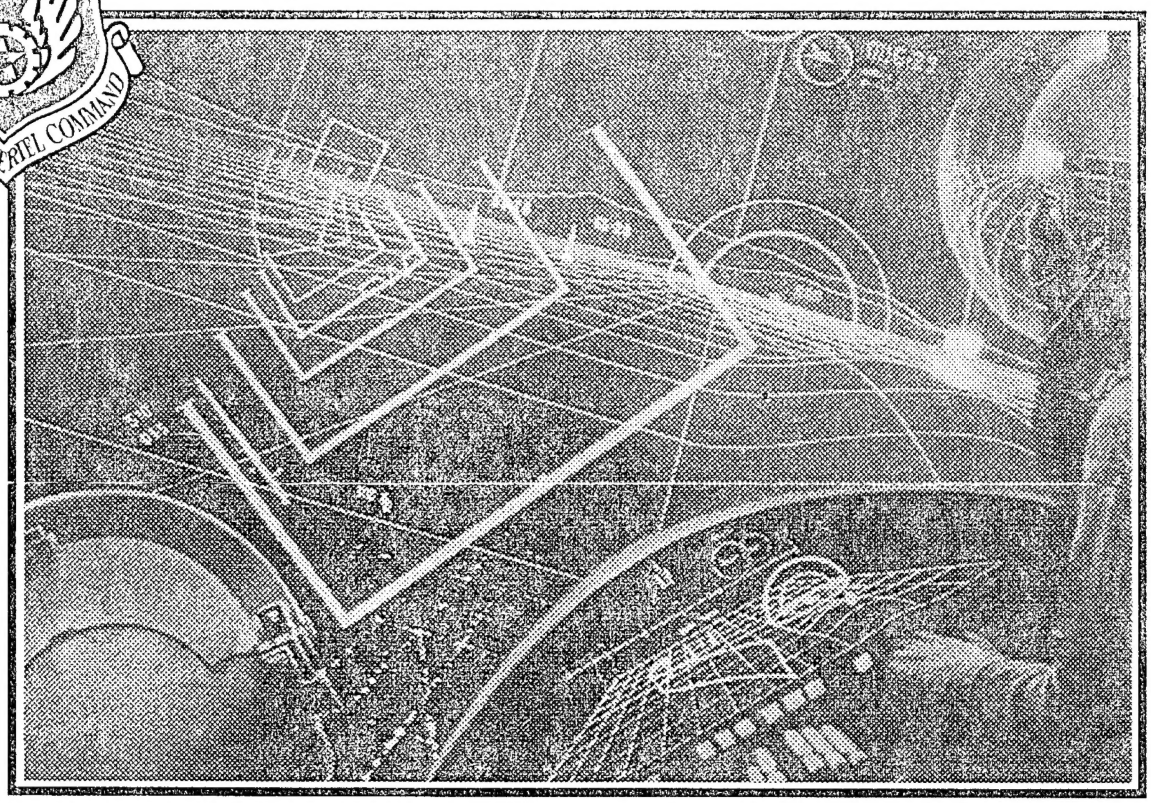
FY 96

HUMAN SYSTEMS

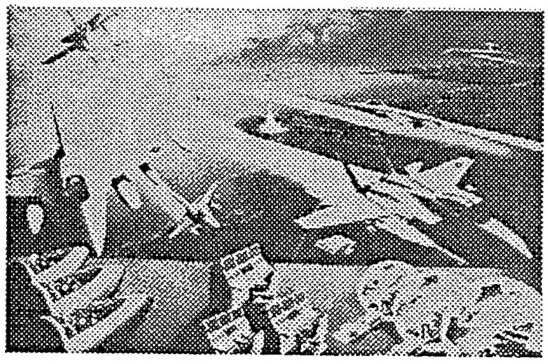
TECHNOLOGY AREA PLAN



HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE & TECHNOLOGY
WRIGHT-PATTERSON AFB OH

Note: This Technology Area Plan (TAP) is a planning document for the FY96-00 S&T program and is based on the President's FY96 Budget Request. It does not reflect the impact of the FY96 Congressional appropriations and FY96-00 budget actions. You should consult AL/XP for specific impacts that the FY96 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 May 1995.

HUMAN SYSTEMS TECHNOLOGY



VISIONS & OPPORTUNITIES

As stated by the Chief of Staff, the mission of the Air Force laboratories is "to ensure technology preeminence of United States air and space forces." The Armstrong Laboratory is the provider-of-choice to meet the Air Force users' needs for human systems science and technology. Our guiding principle is that there are no "unmanned systems" in Air Force operations. The laboratory is unique in the Department of Defense, bringing together in one organization the physical, biomedical, behavioral science and engineering disciplines, and specialized research facilities required to address all aspects of the human role in Air Force combat operations. The scope of the Armstrong Laboratory research and technology programs includes personnel selection and classification, computer based training technology for both air and ground crews, personal protection concepts and criteria, crew performance enhancement in sustained operations, occupational risk assessment, and environmental characterization and remediation technology development.

Five major trends are likely to impact Air Force operations over the next decade:

- A highly mobile, deployed, tactical force relying on the composite wing concept;
- Short-notice, long-duration strategic mission execution from a CONUS-based combination of regular and reserve forces;
- New warfighting strategies focusing on regional threats and crisis response;
- Increased high-technology weaponry coupled with the need for the human operator to successfully cope with the information-rich characteristics of high intensity conflict;
- The continued importance of weapon system affordability and protection of the environment.

The Armstrong Laboratory, as the prime developer of human systems technology, has the opportunity and skills necessary to assure that Air Force personnel are properly selected, trained, equipped, and protected to cope with these trends.

In the future, a smaller force will perform the Air Force combat mission - Global Reach, Global Power. To maintain a high degree of combat readiness and mission performance, the Air Force must place increasing emphasis on "force multiplying" weapon systems and the retention and training of intelligent people for highly complex jobs. We must concentrate our technology programs to exploit the underlying strengths of air power; namely speed, range, precision, lethality, and flexibility.

- In the cockpit, 3-D visual and auditory displays will provide the pilot with an overall view of the surroundings, heightening situational awareness during air combat missions. These same technologies will give the battlefield commander faster information flow for improved command and control.
- The entrance of women into fighter aircraft requires an assessment of cockpit design to identify deficiencies and to develop improved protective

equipment to better accommodate the differences in female anatomy and physiology.

- Air Force recruits will receive basic job training from personal computer-based "intelligent tutors" to gain deeper job understanding. The same technology will emulate one-on-one instruction from a knowledgeable teacher to enhance the quality of mathematics and science education in schools throughout the U.S..
- Pilot candidates will be assigned to particular types of aircraft based on their physiological and psychological profiles as determined by physical exams and specially designed aptitude tests.

The emergence of numerous regional conflicts has shown that Air Force units can be deployed anywhere in the world on short notice, and must be prepared to fight continuously for weeks under self-supporting conditions. The key to bringing such conflicts to a successful conclusion is keeping personnel and equipment at peak efficiency under highly stressful conditions.

- New techniques will enable personnel to overcome fatigue in sustained operations and remain vigilant for extended time periods.
- The myriad of ground equipment associated with aircraft will be combined into one piece of multi-functional equipment. This will reduce the amount of equipment necessary for deployment.

Exotic weapons, such as lasers, are already on the battlefield and the taboos against chemical and biological weapons could disappear if the tide of battle turns against an enemy aggressor. The Air Force must be ready to fight and prevail in these types of hostile environments.

- New life support equipment will protect personnel across the range of possible threats, including conventional and exotic weaponry. Mission adaptive protective ensembles will be designed to enhance mission accomplishment.

The Air Force will experience major funding reductions over the next decade, requiring us to reduce laboratory infrastructure and develop cooperative research and development agreements with academia and industry to aid transfer of human centered technology to the private sector. Additionally, both industry and government will require technologies to help protect and clean the environment.

- Future Air Force systems will incorporate maintenance considerations early in the design to lower life cycle costs and make them more affordable.
- Early environmental analysis will "design out" or mitigate health and safety hazards related to new materials and toxic chemicals prior to use in Air Force and commercial products.
- High operational training costs will drive development of networked simulation to link all the services in a joint training and mission rehearsal environment, and lead to increased readiness at reduced cost.

The human will remain the most critical component of weapon systems well into the 21st century. Advances in human systems technology will ensure that Air Force personnel perform to the best of their ability throughout their career.

This plan has been reviewed by all Air Force Laboratory commanders/directors, and reflects integrated Air Force technology planning. We request Air Force Acquisition Executive approval of the plan.

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Technology Executive Officer

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Director

CONTENTS

INTRODUCTION

BACKGROUND

Research and development in Human Systems technology is committed to enhancing human performance in Air Force systems and occupations. The Human Systems technology program, conducted at the Armstrong Laboratory, provides a full spectrum of research and development to complement the other technology areas of the Air Force Science and Technology (S&T) program (Figure 1).

For many years we have sought to develop technology that extends the capability of the human being in wartime endeavors. As aircraft materials and design have improved, the human pilot has become the physical "weak link" in systems operations. Laboratory scientists and engineers have worked successfully to extend pilot tolerance to high G-forces and high speed ejections. The addition of female pilots to high performance combat aircraft has changed the requirements for protection, and we have embarked on programs to fulfill this need.

Onboard computers provide a tremendous array of data to the human operator. Without the training and display technologies developed by the Armstrong Laboratory, raw information would overload not only pilots and weapons systems operators, but technicians as well. Through our display and analysis technologies, we've turned information into useful tools, extending the mission capabilities as well as human knowledge.

Today's high performance aircraft are expensive, both in terms of initial purchase and life cycle costs. By developing computer-aided analytical tools for logistics, toxicology, and force management, the laboratory has factored the human operator into the process early in systems design, and thereby greatly reduced the life cycle costs for tomorrow's systems.

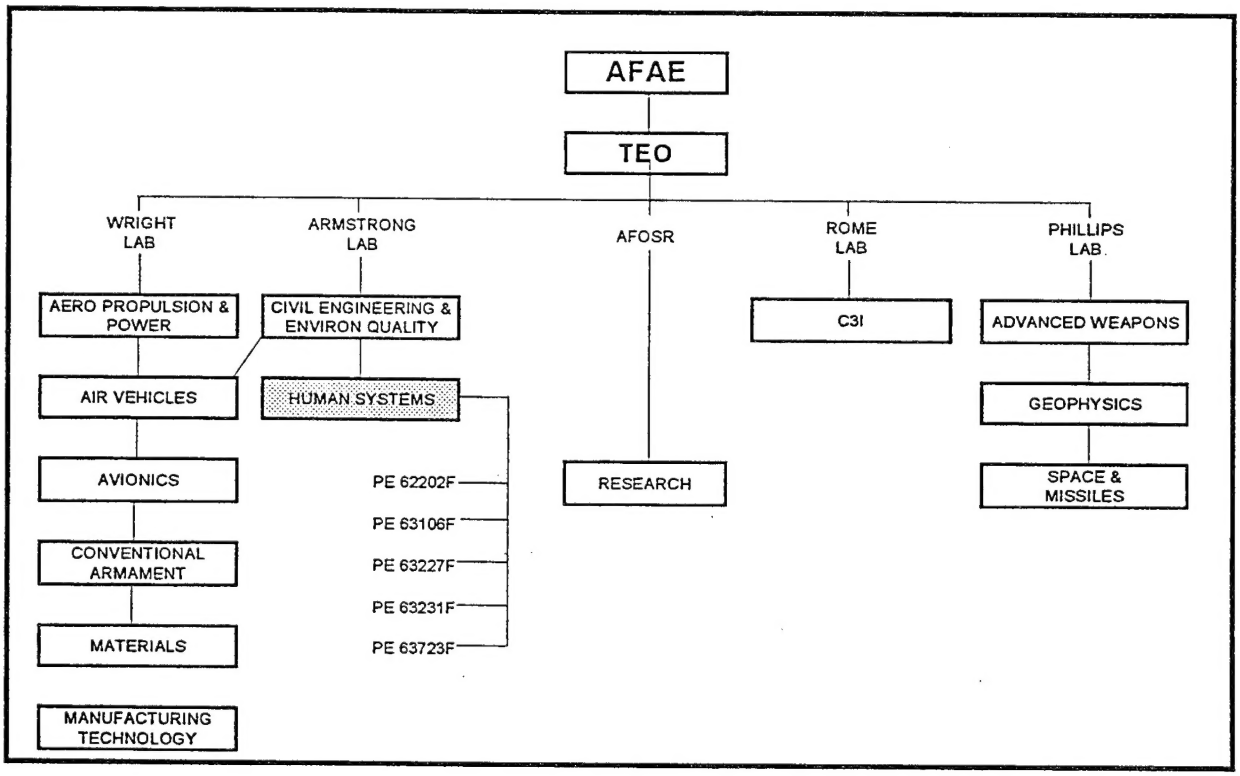


Figure 1 AF S&T Program

By being in the forefront of emerging aeromedical technology, laboratory physicians have developed standards that help determine whether pilots should be grounded because of aeromedical problems. In many cases, this research has kept experienced pilots in the cockpit, extending the time their skills are available to the Air Force.

The Armstrong Laboratory works closely with users to ensure that the products of research meet their needs. One example of our commitment to the user is the Advanced Technology Anti-G Suit (ATAGS) developed to combat G-Induced Loss of Consciousness in high performance aircraft. This new G-suit combines an abdominal pressure bladder with bladders that completely encircle the leg from the hip into the boot. The result is a 60 percent improvement in endurance during high G over the present G-suit. When combined with the positive pressure breathing ensemble, COMBAT EDGE, ATAGS produces greater than a four-fold improvement in endurance. ATAGS has moved from the laboratory to the Human Systems Program Office where it awaits transition to ACC and AETC.

The Air Force allocates over 8 percent of its total S&T budget to Human Systems technology, as shown in Figure 3. (These and all funding figures reflect the FY96 President's Budget Request). The laboratory distributes Air Force S&T resources among its four integrated thrusts as shown in Figure 4.

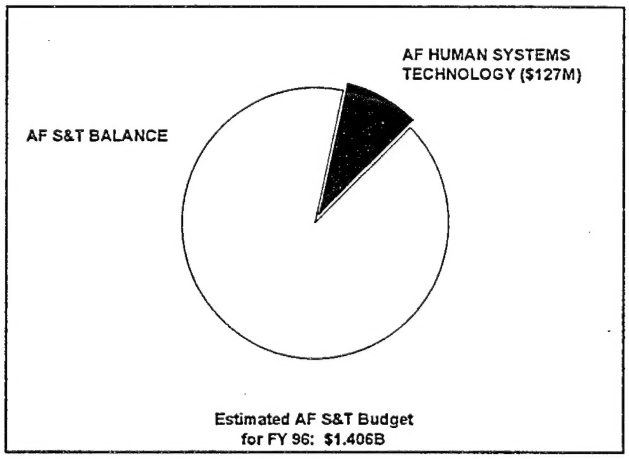


Figure 3. Human Systems *vs* AF S&T

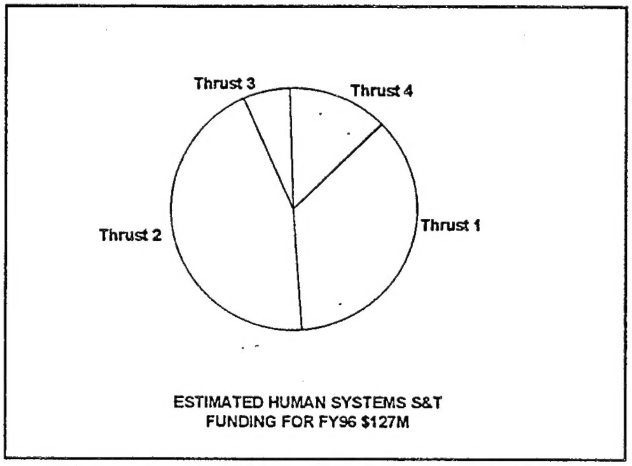


Figure 4. Actual Funding By Major Technology Thrust

Each of the four thrusts, listed in Figure 5, makes a unique contribution to improve the performance of Air Force personnel.

MAJOR TECHNOLOGY THRUSTS	
1.	Crew Systems
2.	Human Resources
3.	Human Biodynamics and Physiology
4.	Occupational and Environmental Health

Figure 5. Major Technology Thrusts

THRUST 1, Crew Systems, provides the design criteria to ensure that new weapon systems are compatible with human operator requirements, and that air and ground crews are protected from physical hazards during air operations. This thrust emphasizes the development of new escape systems, advanced anti-G and altitude protective equipment, laser visors for aircrew protection; and cockpit and display design tools to improve situational awareness and to reduce workload. Products from this thrust transition to the warfighting commands, all of whom have highly ranked this thrust.

THRUST 2, Human Resources, provides technology to assure that the quality of the Air Force's future work force is maintained through improved personnel selection, classification and training, and to enhance the supportability of current and future weapon systems. Emphases in this thrust are on application of artificial intelligence technologies to computer-based training, development of effective new technologies to improve aircrew training and situational awareness, and development

of computer based tools to "design in" maintainability to support systems in the field. The research in the Human Resources thrust directly benefits Air Education and Training Command and Air Force Materiel Command. Additionally, the improvements in training and supportability of weapons systems impact the entire Air Force and, in many cases, industry weapon systems developers and manufacturers as well.

THRUST 3, Human Biodynamics and Physiology, investigates the human biomedical factors affecting performance and awareness in the cockpit, and applies the results to the selection and retention of rated personnel. Current topics include an improved ability to detect cardiovascular disease, the incidence and prevalence of neurologic and psychiatric disorders in crew members, and possible revisions to aeromedical regulations on vision standards. The aeromedical standards defined in this thrust are transitioned to the Surgeon General and, indirectly, to the flying commands.

THRUST 4, Occupational and Environmental Health, produces data used in setting standards and criteria for safeguarding Air Force personnel and the civilian community from occupational and environmental hazards associated with military systems and operations. Present emphasis is directed at toxicity of new products, biological effects of laser and radiofrequency radiation, and impact of noise and sonic booms on humans, animals, and structures. This research supports Air Force compliance with environmental and occupational safety legislation and provides legally defensible data for countering lawsuits against the government.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

Human Systems technology is pervasive across all Air Force operations and is significantly leveraged by complementary research efforts underway in the academic, industrial, and international sectors. There is also close internetting with other technology area programs through formal coordination and memoranda of understanding.

With few exceptions, current Independent Research and Development (IRAD) programs focus on the Crew Systems and Human Resources thrust areas. Significant investments are being made in Crew Centered Cockpit Design methods and in Helmet-Mounted Information technologies. These efforts directly support the joint cockpit technology program sponsored by the Armstrong Laboratory and the Wright Laboratory. In the Human Resources thrust area, major IRAD investments are being made in advanced computing technology, artificial intelligence and large scene visual simulation for training. Advanced computing concepts support and complement Air Force programs to develop low-cost, computer-based training technologies. There is also a growing IRAD investment in logistics technology directly supporting Air Force initiatives in concurrent engineering and operational logistics.

Small Business Innovation Research (SBIR) initiatives in support of all four technology thrusts address the specific needs of the Air Force research programs, as well as produce innovative dual use technology products. Representative technologies range from on board oxygen generating systems to hyperbaric medicine and include an ultrasonic tactile sensor array for the Dextrous Hand. This technology enhances our efforts to use telepresence to permit remote access to hazardous environments. The Utah-based company that developed Dextrous Hand received an R&D 100 Award, and is presently negotiating with a Fortune 500 tire company and Japan to market the technology. A software package, developed under the SBIR program, predicts human body dynamics during aircraft ejection, aircraft crashes, automobile accidents and other very high-G acceleration/deceleration events. Users include aircraft and automobile designers, restraint manufacturers, and insurance underwriters, to name a few, and the interest continues to grow. A recently completed Phase I SBIR effort developed a model to predict eye damage from lasers and its effect on pilot performance by predicting the decrease in visual acuity due to laser lesion in the foveal region. The Phase II work will produce a tool for pharmaceutical companies and doctors to use in visualizing the effects of treatment on patients. This model is expected to replace animals in research on the effects of laser eye damage. Another completed Phase I effort has proven the feasibility of a new kind of hyperbaric oxygen chamber which showed potential cost savings of 70 percent using concrete and constructing rectangular chambers over the conventional steel cylindrical facility. Preliminary arrangements are underway to construct and test a full size rectangular concrete pressure vessel for

human occupancy on Brooks AFB. The San Antonio based company fully demonstrated the commercial market and has received commitments from at least one hospital and interest from several others around the country to construct similar chambers once testing is completed. The proof of concept can lead to significant growth in the hyperbaric oxygen therapy marketplace as more clinics and hospitals will be able to afford a lower cost facility. Numerous feasibility and technology development efforts continue to support initiatives in Crew Systems, Human Resources, Occupational and Environmental Health, and Human Biodynamics and Physiology.

Current Defense Conversion program activities include assessments of Human Systems technologies by outside business strategists to determine which technologies have the greatest commercial potential. Results of these assessments are used in various marketing strategies to identify potential licensees for patented inventions and industrial partners for collaborative research. The Laboratory currently has 17 active Cooperative Research and Development Agreements (CRDAs) and numerous others in various stages of development. In addition, the Laboratory has negotiated three license agreements and has received over $7,000 in up-front royalties. Examples of the technologies being licensed include our molecular sieve oxygen generation system for commercial use in health care, welding and cutting, and other industrial processes where low volume, high purity oxygen is a requirement; and our instructional systems development to determine training requirements and procedures based on equipment design. Two license agreements pertaining to six laboratory patents are currently under negotiation with a local start-up company. It is anticipated that these licensing activities will generate tens of thousands of dollars in royalties to the Laboratory in the near future.

Support of Human Systems technology is also obtained through cooperative International Research and Development efforts. The Armstrong Laboratory has two million of Nunn Program funds. Two memoranda of understanding (MOU) are in place, and four umbrella MOUs have recently been signed which will allow for participation through annexes. We have nearly 20 data exchange agreements with foreign countries. The international program covers the range of Laboratory research and development.

Coordination with other Air Force laboratories has continued to increase as a result of major Air Force laboratory restructuring that occurred in FY91. The Joint Cockpit Office managed by Armstrong Laboratory and Wright Laboratory coordinates a broad cockpit technology development program integrating exploratory and advanced development initiatives within the Human Systems and Air Vehicles technology areas. Previously established collaborative programs in the area of logistics technology with the Wright Laboratory have been strengthened. Wright Laboratory and Armstrong Laboratory also have cooperative programs in the improvement of safe ejection seat envelopes and in the toxicological analysis of Halon replacements and other new materials. A cooperative program to advance directed energy technology has flourished between the Armstrong Laboratory and Phillips Laboratory. Formal technical exchanges have been initiated between the Armstrong Laboratory and the Rome Laboratory to expand cooperation and develop collaborative initiatives in the areas of C3I training and decision aiding, and human-computer interface technology development. Armstrong, Phillips, Rome and Wright Laboratories are cooperating in a program involving fundamental skills training research. Local schools within each laboratory's region are using math and reading tutors to improve students' academic skills. Armstrong Laboratory is using the results from these tests to improve the quality of the tutoring programs.

The Armstrong Laboratory supports the Space Technology Interdependency Group (STIG) via Co-Chairmanship of the STIG Operations Committee. The laboratory has also been very active in relocations under Project Reliance. Six chemical defense researchers are collocated with the Army at Aberdeen Proving Ground MD while three training researchers share Navy facilities in San Diego. A total of 46 Army personnel are collocated at Armstrong Laboratory facilities sharing research ideas in biodynamics, laser and radiofrequency radiation bioeffects, and toxicology. Nearly 50 Navy personnel are projected to move into Armstrong Laboratory facilities. They are in addition to the Navy personnel who for 17 years have worked alongside Air Force researchers making breakthroughs in toxicology. These consolidations save money and, more importantly, increase the quality of research benefiting the users in all services.

CHANGES FROM LAST YEAR

Armstrong Laboratory is developing an integrated, multidisciplinary approach to human systems research. This involves forming teams from all the directorates to attack problems of major interest to the Air Force. Recent examples of this approach are: the Situation Awareness Integration Team assembled to answer CSAF concerns; a Lab team to support Board investigation of the shootdown of helicopters over Iraq; the Advanced Technology Anti-G Suit improving pilot endurance to high, sustained acceleration; and the large rocket motor disposal program to safely remove, treat, and dispose of aged rocket propellants.

The addition of female pilots to combat aircraft has caused a moderate change in our investment strategy to ensure that protective equipment is adequate for safe operation, and future cockpits are designed for a wider range of ergonomic factors.

Finally, Armstrong Laboratory completed two major technology demonstrations and made the technology available for transition. These included the Integrated Maintenance Information System (IMIS) which went to the Integrated Maintenance Data System (IMDS) Program Office and the Assessment System for Aircraft Noise which went to MAJCOMs users to assist them in developing the noise portion of environmental assessments and impact statements.

MAJOR TECHNOLOGY THRUST 1: CREW SYSTEMS

USER NEEDS

- **Joint Helmet-Mounted Cueing System** (USAF/Navy Joint Mission Need Statement (JMNS) and draft Operational Requirements Document (ORD)). Our Helmet-Mounted Sensory Technologies advanced development program addresses the requirement for a day/night helmet-mounted tracker and display (HMT/D) with a line-of-sight aiming system for air-to-air and air-to-ground weapons delivery. This will counter a threat from adversaries possessing a high off-boresight targeting capability. Technology will be leveraged with the Joint Helmet Mounted Cueing System (JHMCS) EMD Program to reduce technical, schedule, and cost risk.
- **Aeromedical Needs** ACC. This is a prioritized set of needs as defined by the Air Combat Command. Crew Systems programs address 20 of 23 near-term needs, 10 of 13 mid-term needs, and five of six long-term needs. Operational priorities such as improved situational awareness, better night vision capabilities, laser eye protection, ejection safe helmet-mounted displays, and performance under high +Gz and high workloads are high on the list of near-term needs. Improvements in display symbology, life support equipment, acoustic localization (3-D audio) technology, and G-LOC (G-Loss of Consciousness) countermeasures rate high for the mid-term. ACC considers advanced visual displays (helmet-mounted, head-up, and head-down) and their integration, improved cognitive capabilities, the full utilization of all human systems (visual, tactile, and auditory), and advanced life support systems in their list of long-term needs. Many of ACC's near-term needs correspond to Human System Needs already identified by the Human Systems Integration (HSI) Technical Planning Integrated Product Team (TPIPT).
- **Women in the Cockpit**. Implementation of the Secretary of Defense decision to open assignments in combat aircraft to women requires changes to flight equipment, cockpits, and emergency escape systems to ensure combat effectiveness and safety. This presents numerous technical challenges. Our efforts to support the accommodation of women in the cockpit are vital to systems such as the F-22, the Joint Primary Aircraft Training System (JPATS), and the Joint Advanced Strike Technology (JAST) demonstration, as well as to system upgrades. Overall cost, injury risk, and mission impacts hinge on the development of adequate technology and the evaluation of existing and developmental aircraft cockpits and flight equipment.

GOALS

To meet our users' needs in Crew Systems, the Armstrong Laboratory (AL) will:

- Provide integrated operator-system visual interfaces for improved information transfer and processing, situational awareness, performance, and safety.
- Expand the performance envelope of emergency escape systems of high-performance aircraft to allow escape at adverse attitudes and speeds of 700 knots.
- Integrate aircrew systems to provide improved protection from altitude exposure, high sustained acceleration, and thermal and other environmental stressors without compromising crew mobility, comfort, and rapid-response capabilities.
- Develop a multidisciplinary, cooperative design environment to create demonstration technologies and evaluate crew systems effectiveness using human-in-the-loop techniques in virtual combat environments.
- Define the ergonomics capabilities and limitations of the female crew member and develop design guidelines and tools to allow weapon systems to accommodate women.

MAJOR ACCOMPLISHMENTS

The Test Planning, Analysis and Evaluation System (Test PAES) was beta tested at over 25 sites within the Department of Defense (DoD) and industry. Test PAES provides a standardized

THRUST 1: CREW SYSTEMS

SUBTHRUSTS

DESIGN TECHNOLOGY

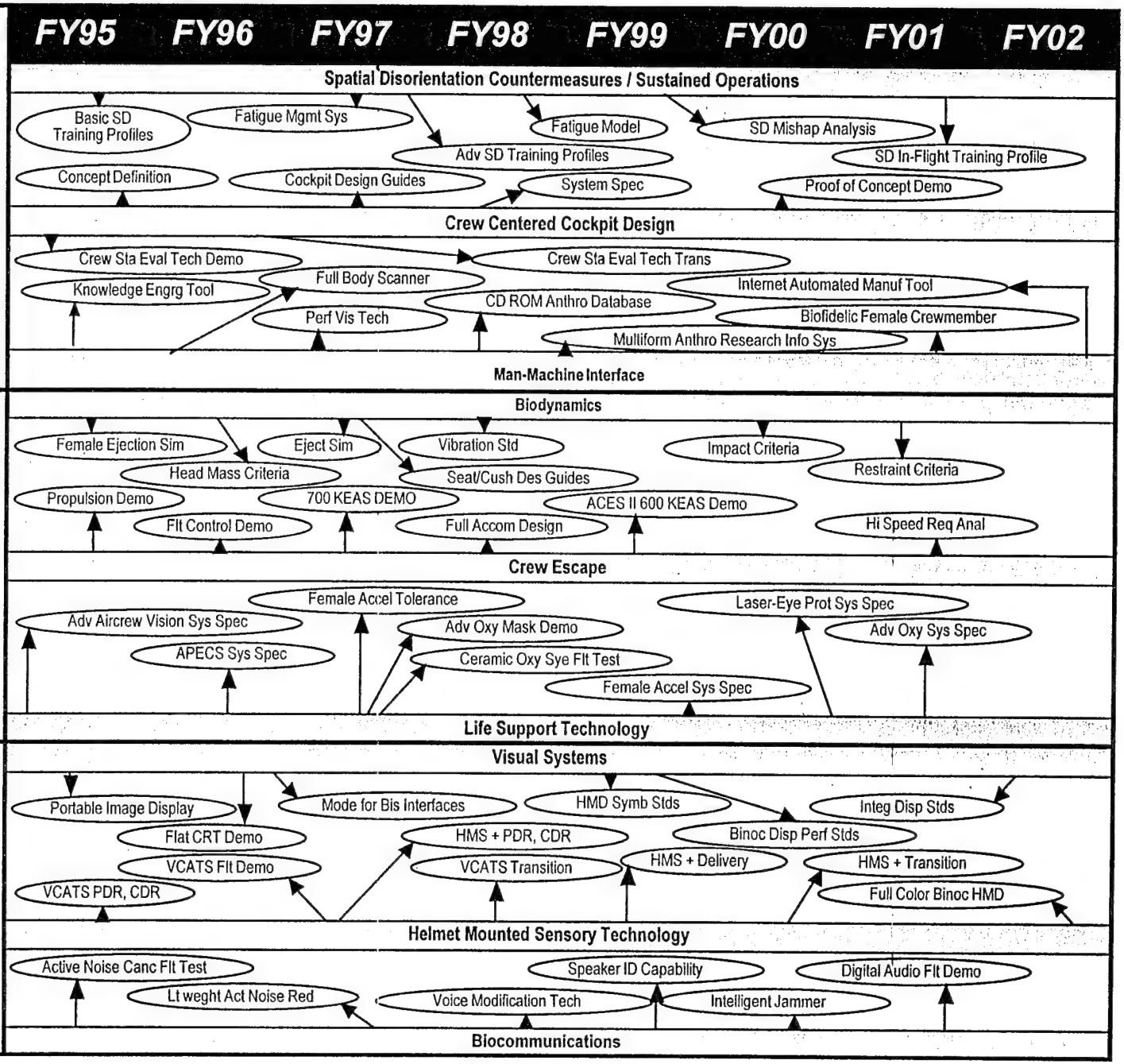
Assure effective integration of human operability considerations into the Air Force systems development process

CREW PROTECTION

Improve the safety and effectiveness of aircrew during operational exposure to mechanical and environmental stress

INFORMATION MANAGEMENT AND DISPLAY

Improve crew performance by defining and improving audio, visual, and other physical and psychological interfaces



process and procedures for crew-station evaluations. Test PAES is being embraced throughout the test community as the model for all testing. Test PAES transition into the DoD Range 2000 program, a tri-service effort sponsored by the Office of the Secretary of Defense, will expand the benefits into other test disciplines. Cooperation with the US Army's Virtual Proving Ground program will establish the Armstrong Laboratory as the Air Force focal point for human performance to support test and evaluation.

Our acceleration research programs have shown that a properly fitting anti-G system is critical to providing adequate protection against G forces. The lack of gender-friendly equipment places female aviators at increased risk and diminishes their ability to fly, fight, and win. The standard anti-G suit was designed to fit males. Our investigators have developed technology for modifying currently deployed garments to properly fit the female form. We have modified suits worn by two of the first women in F-16 training at Luke AFB. Both pilots had difficulty in achieving good anti-G suit fit and experienced discomfort in flight upon suit inflation. This impacted their performance during high +Gz acceleration. The anti-G suit modifications were made, the suits were rated safe-to-fly, and both women are now flying operationally in the modified garments. Both pilots reported the AL modification significantly improved the comfort and performance of the standard anti-G suit.

The efficiency of the high purity molecular sieve oxygen generation system (HP-MSOGS) was dramatically improved to provide greater quantities of high purity oxygen. A scaled-up HP-MSOGS produced approximately 5 liters per minute of 99 percent oxygen (a fivefold increase from an earlier model). The HP-MSOGS uses an AL patented technique which separates nitrogen and argon from air in a one-step process. The HP-MSOGS could provide medical grade oxygen for respiratory therapy and trauma care at forward-based locations, such as air transportable hospitals and could generate oxygen for aircrew breathing. High purity oxygen would reduce the risks associated with high altitude flight and rapid decompressions. This will reduce the number of cargo aircraft sorties needed to resupply oxygen.

Active Noise Cancellation (ANC) was successfully demonstrated in flight tests with a NASA OV-10 twin-engine propeller aircraft. The ANC system accurately controls the turning speed and phase of each engine, adjusting each to minimize the noise level during cruise and under the aircraft during takeoff and landing. Aircraft interior noise levels decreased by 10 decibels (dB) and noise radiated to the ground was decreased 3 dB during takeoff, flyovers at multiple altitudes, and landing. If these effects can be duplicated in other twin-engine turbo-prop aircraft, then ANC has significant potential in reducing the detectability range of special operations aircraft and in noise reduction for commercial aircraft. Active Noise Cancellation development plans include additional flight tests in the NASA OV-10 and a commercial twin-engine aircraft, installation on the inboard engines of an AF Special Operations Command aircraft and a four-engine commercial aircraft.

Under a Phase III Small Business Innovation Research program, the Joint Special Operations Command (JSOC) funded the development of a 60-degree wide field-of-view night vision goggle (NVG) system (NOVA-8). The NOVA-8 is being developed as a retrofit to the currently fielded 40-degree Aviator Night Vision Imaging System NVG and offers an increase in night viewing area of over 150 percent. A revolutionary fiber optic twister/expander design, the critical component in the NOVA-8 optical path, makes this wide field-of-view possible. Three systems were delivered to JSOC for field testing in FY95.

The mental workload of Air Force pilots and other operators of complex systems can be very high. The Workload Assessment Monitor (WAM) was developed to provide a method of continuously monitoring workload in real time. This continuous workload information must be provided to the system so that corrections can be made to reduce pilot workload. Cardiac, eye, respiration and brain wave data are collected and reduced on-line so that estimates of operator mental workload can be continuously updated. This procedure takes advantage of the unique response pattern of each operator by establishing individualized mental workload levels. Conditions of underload resulting from continuous operations and fatigue could also be detected by the WAM. The WAM can currently be used in simulator and laboratory settings.

The circadian clock, a biological function located in the brain, is the central component of the human fatigue management system and ensures optimal performance during the day. Travel across several time zones, as well as sustained operations involving night work, confuse the circadian clock, resulting in impaired performance that usually lasts for several days. Research conducted at the Armstrong Laboratory, with assistance from AFOSR, has identified two biochemicals in the brain that are responsible for resetting the circadian clock. One of these chemicals, called serotonin, can be manipulated using currently approved pharmaceuticals. As a result, we were able to reset the circadian clock by eight hours in a single day. This work has been applied to reduced fatigue effects in aircrew members on long duration flights.

Under a Cooperative Research and Development Agreement, we evaluated advanced avionics capabilities that support precision weapon delivery. An information requirements analysis was conducted to assess the impact of these new capabilities on crew station design requirements. They included: Global Positioning System (GPS)-aided weapons, relative targeting with synthetic aperture radar, automatic scene correlation, and attack against a target with multiple/distributed aimpoints As a result, the tactical situation display, stores management display, and radar imagery display formats were modified and an innovative reference imagery display was designed.

A Foreign Comparative Testing (FCT) program was accomplished as a joint USAF/USN program to assess the ejection seat technology of the former Soviet Union. The primary objective was to evaluate the high-speed escape capability of the K-36 ejection seat, which is used in all contemporary Russian aircraft. The Russian design bureau, Zvezda, claims the seat provides safe escape up to 755 knots equivalent air speed (KEAS), using mechanical windblast protection and seat stabilization techniques. The FCT program was conducted using more advanced Russian test facilities, featuring in-flight ejection capabilities from a MiG-25 at speeds up to Mach 2.5 at 50,000 feet. Eleven successful high-speed ejections were completed at speeds up to 728 KEAS. Test results indicate the K-36 seat provides stability, windblast protection, and reduced occupant accelerations at airspeeds beyond those thought feasible using simple mechanical devices. The K-36 ejection seat FCT program has demonstrated a successful business method using a US contractor and a Russian joint-venture-abroad legal agreement. The K-36 technology could be used to improve existing ejection seats or used as part of an advanced system design.

CHANGES FROM LAST YEAR

By direction of the Joint Directors of Laboratories (JDL), a new JDL Technology Panel was formed to coordinate all DoD work in Human Systems Interface (HSI) technology under the Defense Reliance Initiative. The action recognized HSI as one of twenty-one Key Technologies within the DoD Science and Technology program. Crew Systems chaired the new JDL Panel and a tri-service Panel Membership was formed, consisting of 39 senior technology managers from the service Laboratories and Centers. During its first year, the Panel organized a logical taxonomy for representing the tri-service work, drafted an executive strategy document, and produced the first-ever comprehensive baseline report and assessment of the entire defense investment in HSI. Continuing taxonomy streamlining, data refinement, and the monitoring of program status and plans, ensure the services will sustain and advance HSI as a key technology for national defense into the 21st century.

In conjunction with Wright Laboratory, we are engaged in the Joint Advanced Strike Technology (JAST) program through its Flight Systems Integrated Product Team. We will provide visual and aural symbology for a helmet-mounted display, to be flight tested by the end of FY95. Other joint projects are under development to meet the improved affordability, risk reduction and single place cockpit goals of the JAST Program. Active noise reduction and speech synthesis are likely candidates for follow-on integration and test.

MILESTONES

The development of a new generation of design tools began with the FY94 delivery of the Computer Aided System Human Engineering: Performance Visualization System. Test and evaluation of the technology was conducted in FY95. In FY96 we will demonstrate the concept of a virtual computer-aided design (CAD) technology for visualization of cockpit accommodation, and complete validation tests for

tactical, transport, and strategic cockpit design applications. A concept demonstration for collaborative computing interface technology for Integrated Product Teams will be conducted in FY98. The proof of concept for the Integrated Advanced Design Support technology will occur in FY01.

To expand the escape system performance envelope, we are working with Wright Laboratory and the Navy to improve ejection seat subsystem technologies. These improvements will be completed in FY97 and will enable safe ejections at speeds of 700 KEAS. They will also improve ejection system supportability and maintainability. Subsystems under development include thrust vectored propulsion, flight control, windblast protection, and limb restraint. Upon successful completion of ground tests at the Holloman AFB High Speed Test Track in FY98, the subsystems will be made available for transition to EMD.

The advanced life support systems required by the Air Force and Navy depend on solving the address thecritical issues of high-G protection, oxygen mask operation and compatibility, and laser-eye protection. Personal cooling concepts for the F-15 and F-16 will be developed in FY95, with F-16 flight testing in FY98. The Female Acceleration Tolerance Enhancement (FATE) program will provide the right equipment and procedures to maximize acceleration performance, regardless of gender, in FY96. The Advanced Aircrew Oxygen Mask effort could offer solutions to problems of mask fit under high acceleration and the high mask pressures required by the COMBAT EDGE system. Improved sizing schemes will be developed and rapid prototyping technology will be exploited to investigate a new approach to custom-fit masks. Transition to EMD is expected in FY97. Developed in cooperation with Wright Laboratory, laser-eye protective visors for day/night operation against current threats were made available for transition in FY95. Protection from agile laser threats and thermal flash blindness will be developed by FY00, as will improved pilot ballistic protection equipment.

The Visually-Coupled Acquisition and Targeting System (VCATS), a helmet-mounted tracker and display technology, exploits the increased capabilities of new high off-boresight missiles. It reduces acquisition time for air-to-air engagements, improving pilot situational awareness and performance. To prepare VCATS for the users, an improved head tracker and a standardized helmet-vehicle interface consisting of advanced connectors, electronics, and wiring harness were delivered in FY95. These will be integrated with the helmet in FY96 and installed in a simulator for demonstration and training. The integrated technology will be demonstrated in an operational F-15 and made available for transition in FY97.

MAJOR TECHNOLOGY THRUST 2: HUMAN RESOURCES

USER NEEDS

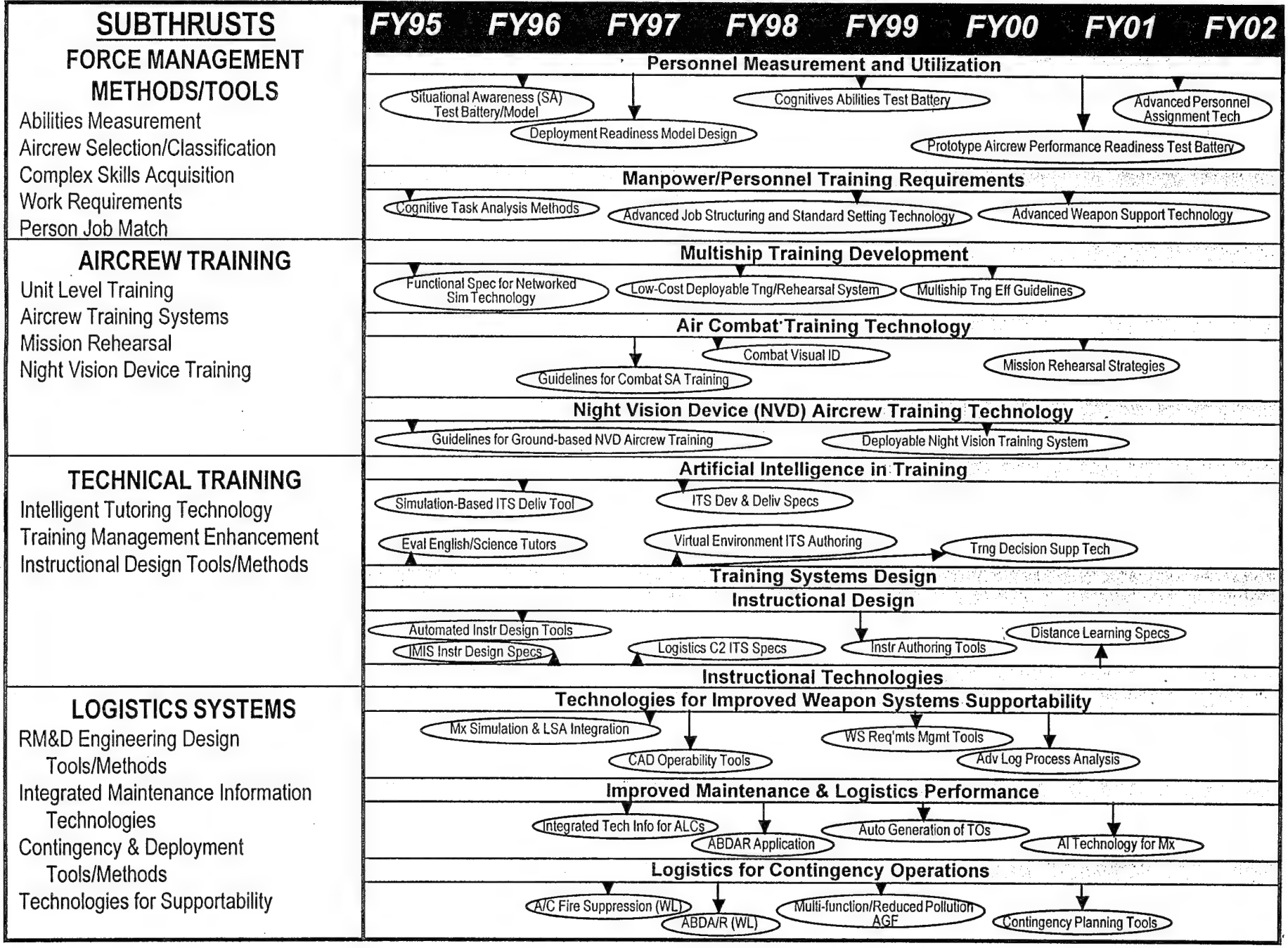
- **Personnel Selection and Classification** (USAF/DP and Tech Push). The AF requires state-of-the-art methods to select and classify top quality personnel for jobs.
- **Manpower, Personnel and Training in Acquisition Decisions Support System** (USAF/PE). The AF requires the technology to integrate manpower, personnel, and training considerations into all phases of the acquisition process.
- **Job Structuring Technology** (AF/DP, Joint Staff) require an ability to determine job requirements and performance standards based on measures of force readiness and mission accomplishment.
- **Aircrew and Maintenance Training Systems and Devices** (SAC/YWB and Tech Push). As the AF draws down its bases overseas, it will need to provide deployable training capability to its aircrews on temporary duty to remote locations.
- **Situational Awareness Research.** The Air Force needs to measure and train situational awareness. Applications include the training of team skills for combat visual identification.
- **Night Vision Device Training** (AFSOC). The DoD needs deployable ground-based training for night vision devices to effectively utilize the technology and prepare aircrews to fight at night.
- **Mission Rehearsal Strategies and Measures of Effectiveness** (AETC, AFSOC). AF Special Operations Forces and AETC need simulation mission rehearsal strategies and measures of effectiveness to train aircrew.
- **Development of Computer Based Instruction Technology** (AETC). AETC, DoD and US agencies need technology to enable subject matter experts, without specialized instructional design training/experience, to develop increasingly powerful computer based and multi-media instruction.
- **Development of Artificial Intelligence for Technical Training Applications Technology** (AETC). AETC, DoD and US agencies need authoring technologies that will reduce the cost and time needed to produce intelligent tutors.
- **Development of Techniques for Improved Training Planning and Evaluation** (AETC). DoD and US agencies need advanced assessment, evaluation, and requirements planning methodologies.
- **Technologies for Contingency and Deployment Support** (ACC, AFMC, AMC). The need to decrease the deployment "footprint" and overall support "tail" for logistics has been explicitly highlighted as a major concern of both ACC and AMC.
- **Integrated Technical Information for Field and Depot Maintenance** (All operating MAJCOMs and AFMC). All commands are vitally interested in reducing the cost of flightline and depot maintenance through maximum use of advanced electronic troubleshooting aids and electronic technical manuals.
- **Technology for Design and Maintenance** (AFMC and Tech Push). US airframe builders, depot maintainers, and commercial industry need aircraft support technologies, design trade-off tools, and business re-engineering tools to provide increased productivity and reduce operational costs.

GOALS

In order to meet our users' needs in Human Resources, the Armstrong Laboratory will:

- Develop state-of-the art methods to select and place personnel into jobs based on their performance potential.
- Develop decision support technology to enable systems planners to incorporate manpower, personnel and training considerations into each phase of the development process.
- Develop job structuring technology to maximize individual and unit/force readiness at lower accession/training/utilization costs. Develop simulation technology for portable networked aircrew trainers that cost one-tenth the amount of fixed simulators.

THRUST 2: HUMAN RESOURCES



- Develop and evaluate deployable night vision device training technology.
- Develop and evaluate networked air combat synthetic environments that allow unconstrained training of wartime skills.
- Develop technology to enable subject matter experts to develop powerful computer-based instruction in one-tenth the time, at one-tenth of the cost of current methods.
- Make intelligent tutors affordable through low-cost authoring technology.
- Develop methodologies to help managers make informed decisions on personnel training and career planning, optimizing the return on their training investment.
- Develop technologies to increase the supportability and affordability of Air Force weapon systems and their supporting infrastructure.
- Extend work in pilot ability test systems, aircraft life extension, airborne fire detection and suppression, aircraft battle damage assessment and repair and multifunction support equipment.

MAJOR ACCOMPLISHMENTS

In cooperation with Army and Navy laboratories under Project Reliance we developed and evaluated the Multi-Service Training Testbed. This program established a permanent network of aircraft, tank, and laser target designation simulators to determine optimum training for the Close Air Support mission using synthetic environments. Four weeks of exercises were conducted using warriors from all the services to develop preliminary training guidelines.

The newly developed Night Vision Goggle training course was approved as the official AF standard and transitioned to the Air Education and Training Command (AETC). Air Force, Navy and Marine Corps, foreign military and law enforcement instructors attended the Night Vision Goggle (NVG) instructor course.

The initial F-16 Multi-Task Trainer was the first simulator-certified for aircrew training by the Air Force and delivered to the Air National Guard. This low-cost ($750K), deployable, full-function Operational Flight trainer established a new standard in aircrew unit-level training devices. These trainers were linked long-haul to a major DoD networked exercise called the Synthetic Theater of War in Europe (STOW-E). STOW-E was a multi-national synthetic exercise that combined live, constructive and virtual entities to train thousands of NATO troops in Europe and the US and was observed by the Joint Chiefs of Staff.

A technology demonstration of theJob Skills Tutor was delivered to Air Combat Command. These tutors shortened training time for hydraulics technicians on the flightline so that a technician with three years experience performed comparable to a technician with ten years experience.

Force management technology development produced several products to aid Air Force managers. A unique selection and classification testing platform was developed which can estimate the values of new personnel assessment and/or classification standards/policies. This system was made available to all other military services. In our role as the joint service lead in job structuring research, we completed an extensive analysis on the Air Force and Navy processes. All major components of the Manpower, Personnel, and Training Decision Support System (MPT DSS) were received, including the Data Base Integration and Analytical/Life Cycle Costs tools. These tools were successfully tested in a joint military/industrial test and evaluation program.

A prototype version of a software tool to rapidly develop low-cost intelligent tutoring systems was completed and transitioned to AETC, AFSOC, AFSPACECOM, AIA, both directly and through the System Program Office. The Fundamental Skills Word Problem Solving Tutor was licensed to an educational publishing company in Boston, Massachusetts. This tutor has consistently produced an average improvement of 26 percent in student problem solving skills. In addition, we doubled the number of schools participating in the Fundamental Skills project from 9 to 18, as we conducted large-scale field testing on the Reading/Writing tutor and began pilot testing the Science tutor. We also delivered the world's first virtual environment authoring technology for training.

New analytic and computer-based tools to improve deployability, affordability, and operation for systems were developed and fielded. These tools are very reliable which is especially important in a deployed location. We identified user requirements for logistics technologies to support rapid and flexible deployments, joint-service operations, wing-level information systems, and integrated information

systems to support Programmed Depot Maintenance (PDM). Some of these new tools supported the B-1B and E-3 PDM lines at Oklahoma City ALC.

This year the Integrated Maintenance Information System (IMIS) completed it's final major field demonstration at the 310 Fighter Squadron, Luke AFB AZ. The DoD Interactive Electronic Technical Manual (IETM) specifications are the bedrock upon which the services will develop and implement paperless technical order data. The IETM is based largely on the IMIS program. Transition of IMIS has already been made to the F-22, F-16, J-STARS, and B-2 offices, and now final transition has been made to the Integrated Maintenance Data System (IMDS) Program Office at Electronic Systems Center for full AF implementation.

Significant progress was made on modeling and design analysis tools that allow users to work with new systems designs and capabilities before the systems are actually built. Several trial applications have been made in coordination with the B-1B program managers at Oklahoma City ALC. This unique combination of software can simulate human maintenance performance with physically accurate computer animated models.

Advanced information modeling tools, essential to business process engineering and process control, have been developed and are under active field test at a number of locations including Oklahoma City ALC. These tools are critical to meet logistics support challenges of reduced manning and budget. Preliminary analytic and simulation models were developed to allow users to assess the impact of rapidly evolving scenarios on logistics support operations at home station and in a variety of deployed scenarios.

MILESTONES

An experimental Situational Awareness Test Battery for selecting pilot training applicants will be evaluated to determine if test scores are useful in forecasting success in Specialized Undergraduate Pilot Training. Computer-based test stations will be deployed to pilot training bases and student pilots will be tested at the beginning of training. The data collection effort will require three years because of the length of undergraduate pilot training and the number of persons who must be tested on each of the alternative forms of the test battery to obtain statistically meaningful results. The FY96 milestone is to deploy test stations to pilot training bases at Laughlin AFB, Columbus AFB, Vance AFB and Reese AFB, to initiate test data collection concurrently and to set up tests score data bases for future analyses.

The Advanced Personnel Test (APT) project is developing experimental computer-based tests to select and classify personnel. These tests are an attempt to measure individual abilities independent from prior learning and cultural experiences. The APT project began a large scale data gathering effort in FY 94 that will continue through FY99. The APT test battery will be administered to thousands of Air Force recruits in order to obtain the statistical power necessary to eliminate ethnic and gender issues in job testing. In FY97 we will begin to examine these tests for potential operational use. In FY99 we will complete data collection and analyses for a recommendation on whether to implement the APT tests for operational use. In FY 96 we will initiate a large-scale effort to identify underlying mental abilities required for complex jobs. This effort will be accomplished in conjunction with the Department of Labor and will culminate in job performance assessment technologies.

The initial Manpower, Personnel and Training (MPT) decision support technology (DSS) is a family of analysis tools that weapon system planners and designers can use to estimate MPT requirements early in the system design process. Optimizing these requirements leads to lower life-cycle costs. The technology will be delivered to AF, DoD and industry users in FY 97. Enhancements planned for the MPT DSS in FY 97 include a workforce simulator for manpower analysis and an extensive training program for potential DSS users. By the end of FY 97, we will have made a critical link of individual aptitude/experience to training time and job performance as well as job task learning difficulty and have completed a front-end analysis of necessary person-job information for more efficient wartime personnel utilization. These advances will lead to a joint job structuring decision support system by FY 98 to include performance-based job standards by FY 99. Following this effort, we will initiate work to extend the MPT decision support technology to plan for human system integration in space, electronic, and support equipment. This technology, the Advance Weapon Support System Acquisition

Model, will see its initial design phase completed in FY 98 with model delivery in 2000.

Full color, high-fidelity, low-cost helmet-mounted display technologies for simulators will be available in FY 96. Also in FY96 the Mission Rehearsal Strategies and Effectiveness measures will address effective use of new mission rehearsal devices, including Special Operations Forces Equipment. We will complete a Night vision Device training system demonstration by FY98. For FY98, we will produce a set of visual guidelines for use in developing enhanced war-fighting training capabilities. For FY99 we will develop a four-ship fighter simulation capability that will allow unconstrained training for a full Combat Air Force flight. The four-ship will be networked to other combat element entities (virtual, live, and constructive) in other locations.

In both training and education, we continue to emphasize the needs of both DoD and public sector users through the development of intelligent training technologies, especially those with strong dual-use applications. In doing so, we dramatically reduce expense and effort associated with training development and delivery. In FY96, we'll begin the final stage of field testing for the Fundamental Skills Science tutor as we license the completed and fully-validated Reading/Writing tutor for commercial sale. At the same time, we'll be completing formative evaluation of the experimental instructional design advisor for novice trainers, and we'll field the first version of our broad spectrum education and training assessment guidelines. In FY97, we'll complete our large-scale research with the public schools and make the Fundamental Skills Science tutor available for commercialization. We'll initiate large-scale field testing of our authoring shell for virtual environments (VE) by developing numerous VE-based tutors to meet a growing list of customer requirements in this area. Training decision support technology will be fully transitioned to the operational Air Force and we'll be fully involved in the evaluation of advanced distance learning technologies.

In FY96, we will develop and field-test analytic and computer-based tools to assess weapon systems affordability and supportability. The unique user requirements associated with rapid deployment scenarios and joint service operations will also be identified. In particular, we will work with other AFMC agencies and DoD services to identify how rapid deployments impact logistics at the home station and at deployed locations. Identification of unique user requirements for logistics technologies to support rapid and flexible deployments, joint-service operations, and wing-level information systems and integrated information systems to support Programmed Depot Maintenance at the Air Logistics Centers are continuing special challenges this year. Towards this end, a special analysis will identify how these changes are likely to impact logistics support operations at home station and in a variety of deployed scenarios.

There will also be greater focus on the engineering aspects of support, with reduced time between user requirement and product delivery. Special attention will be directed towards reducing the deployment footprint by assessing the operational and support implications of multifunction aerospace ground support equipment (AGE). As the AF R&D focal point for improved reliability, maintainability, supportability and deployability for aerospace support equipment, we will serve as integrating agency to plan and assess the feasibility of remediation of environmental non-compliance of common AGE. With Integrated Weapon System Management now becoming fully implemented, synthetic environments using advanced analysis and simulation tools will soon allow assessment of manufacturing, production, logistics deployment readiness and weapon system operational suitability prior to manufacture or retrofit.

In a joint program with Wright Laboratory, we will combine previously developed digital information systems and advanced computer graphics to develop a self-contained, hand-held aircraft battle damage accident assessment and repair aids. This will allow field personnel to make rapid, on-site judgments regarding aircraft mission capability and dramatically reduce the requirement for volumes of supporting paper technical data and large number of engineering specialists. We will also complete a user requirement analysis to identify needs of ALCs in aircraft maintenance and modification with direct impact on aircraft life extension (aging aircraft). Since much of the work accomplished in this subthrust is applicable across services, many of these programs are done in coordination with Army and Navy agencies.

MAJOR TECHNOLOGY THRUST 3: HUMAN BIODYNAMICS AND PHYSIOLOGY

USER NEEDS

- **Human Systems Needs Statement** (ACC). Evaluate altitude-induced vision loss and rigid gas-permeable contact lens for USAF aircrew. Develop an aircrew safety spectacle frame that is compatible with current life support equipment and that is proven to be an operational improvement on the current design.
- **Development of Aeromedical Standards** (ACC, AMC, AFSOC). Conduct human performance research to identify militarily significant physiological risk factors. Develop a protocol for evaluation of medication for their effects on human performance in aviation. Standardize physical standards for USAF special tactics teams with US Army Rangers, US Navy Seals, and Coalition special operations forces. Determine the utility of refractive eye surgery for aircrew. Determine the attributes of the successful aircrew, to include mission and weapons systems' specific attributes. Improve tools for aircrew selection, including physical and psychological testing. Conduct acceleration research by assessing the impact of coronary artery disease in the high-G environment and evaluating the aeromedical significance of various G-induced cardiac dysrhythmias. Conduct visual performance testing in the high-G environment. Assess risk of embolic/ischemic event from acute G forces. Develop a tool to detect asymptomatic cardiac ischemia. Develop aircrew laser surveillance and color testing methodologies.
- **Development of Aeromedical Services** (AETC). Conduct successful and efficient individual screening of enlisted, line officer, and health professionals in support of the national military strategy. Develop a more sensitive and specific diagnostic test to identify glaucoma susceptible individuals. Support the USAF Recruiting Service to select recruits on performance-based criteria.
- **Operational Performance Enhancement Devices and Physiological Optimization** (AFSOC, ACC). Evaluate and improve visual performance of night vision systems. Determine night vision goggle performance across the interface spectrum of a normal to a diseased state eye. Research, establish, and improve upon a contact lens program for aircrew. Deliver a dust/wind protective goggle compatible with current life support equipment. Determine how to enhance aircrew fitness and thereby performance. Conduct gender specific physiological research related to the operational environment. Develop bioaerosol particle detection system.
- **Tasking from USAF Surgeon General** (AF/SG). Evaluate aircrew with difficult, obscure, or borderline biomedical problems, as well as aircrew being considered for special flight operations. Conduct a thorough evaluation of referred aircrew problems, specialized studies and confirmatory examinations, and make a disposition recommendation to the certification or waiver authority.

GOALS

In order to meet our users' needs in Human Biodynamics and Physiology, the Armstrong Laboratory will:

- Develop and provide optimal and current aeromedical selection, classification, and retention tools to preserve and enhance the flying force. This will be accomplished through the following activities:
  - Maintain an ongoing, current, and accessible aeromedical standards database that identifies disease cohorts, subsets, and cofactors in the aircrew population.
  - Identify physiological risk factors which adversely impact aircrew operational success.
  - Detect diseases with long asymptomatic latent periods in candidate aircrew trainees prior to training.
  - Develop improved tools for disease assessment to permit early intervention in order to decelerate the rate of progression of

THRUST 3: HUMAN BIODYNAMICS AND PHYSIOLOGY

SUBTHRUSTS

AIRCREW STANDARDS RESEARCH

Provide medical selection criteria in extending the flying lifetime of current pilots by reducing medical groundings

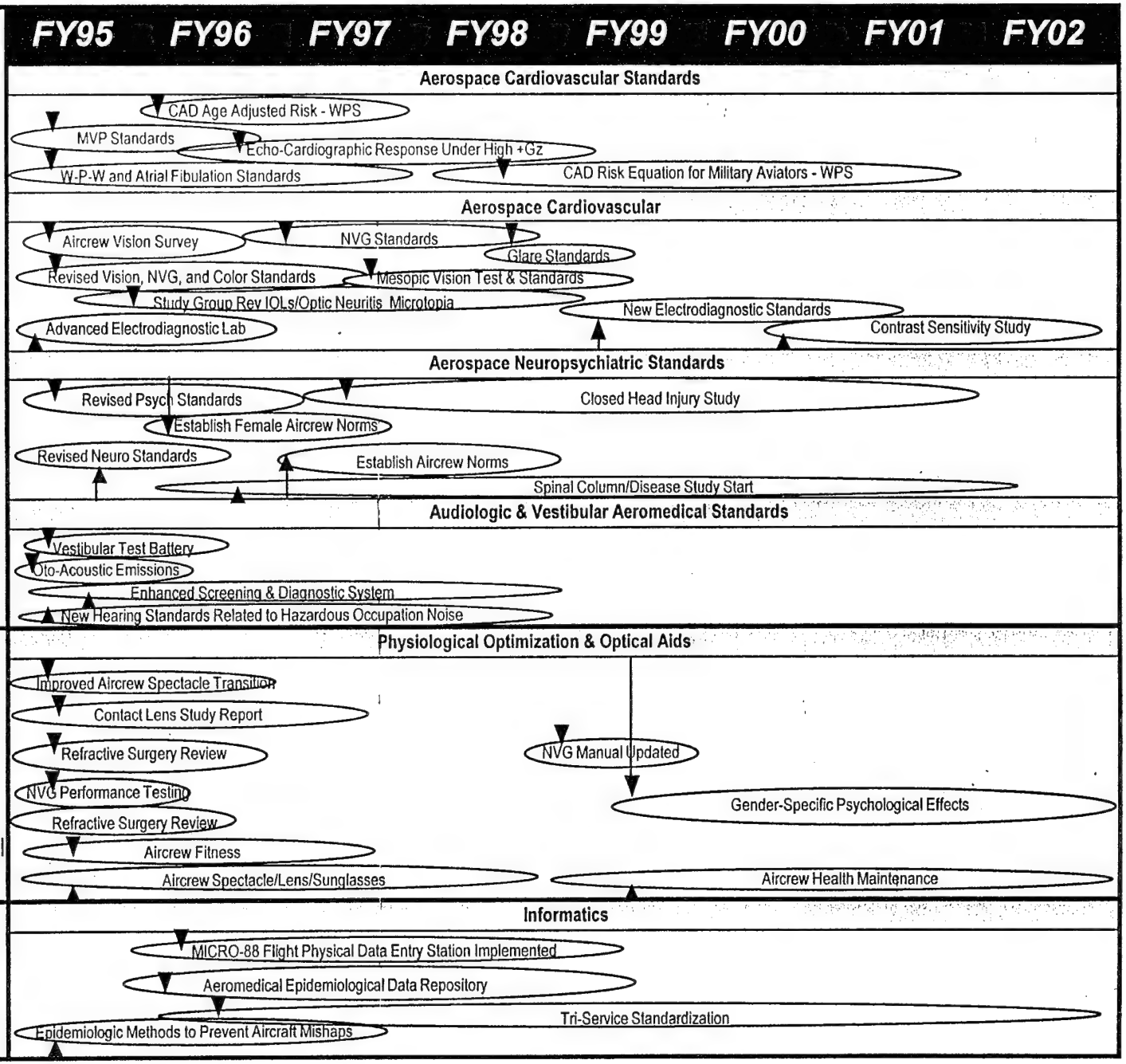
Disease - Early Detection and Definition of Effects

OPERATIONAL PERFORMANCE ENHANCEMENT

Enhance and protect aircrew performance-
- Optical & Visual Appliances
- Gender-Specific Physiological Effects

AEROMEDICAL INFORMATICS

Assess & Linkage - All levels USAF Aeromedical Standards



the disease, and to prevent morbidity and premature mortality.

- Develop objective guidelines to remove from flying status, either temporarily or permanently, those aircrew with clinical or preclinical disease which pose an unacceptable risk to flying safety.
- Develop personality/psychiatric screening tools which would facilitate the establishment of existing aircrew norms and identification of successful aircrew.
- Develop tools to delineate unique psychological/aeromedical needs of female aviators in deployment and combat situations and all aviators in mixed-gender units.
- Develop noninvasive audiologic and vestibular diagnostic systems to identify individuals more susceptible to noise injury, develop new standards for exposure to hazardous occupational noise, detect early-stage vestibular disease and evaluate vestibular performance.
- Develop an informatics system, which includes a computerized flying physical examination database, to give access to and link all levels of the USAF aeromedical system

- Enhance and protect aircrew performance by:
  - Developing optical and visual appliances and protective devices.
  - Conducting physiological research to define aircrew fitness, health, and gender-related factors.

MAJOR ACCOMPLISHMENTS

A comprehensive review of 102 aviators evaluated for ventricular tachycardia (VT) by the Aerospace Medicine Consultation Service (ACS) was completed. It had a 99.5% follow-up over an average duration of 10.6 years. This review, a culmination of over 30 years of follow-up, resulted in a significant expansion of waiver criteria, doubling the number of those returned to flying status.

Vision research yielded new, more comprehensive color vision standards, which were recommended to the AF/SG, and reflect appropriate operational requirements for modern aircraft. A new eye laser damage surveillance methodology for aircrew was recommended. This methodology reflects the proliferation of laser threats both from military applications and emerging commercial hazards near our bases. The night vision goggle (NVG) performance testing program completed the evaluation of dark adaptometry after NVG use as a model to analyze recovery time following operational NVG failure. Additional enhancements to the comprehensive night vision device performance program included the development of an NVG preflight test lane with specialized chart and infrared illuminator allowing aircrew to properly assess and adjust their NVG prior to flight. Investigations of NVG performance at altitude were completed and the results briefed to AFSOC for implementation.

The proposed new aircrew spectacle frame received seven modifications designed to enhance its comfort, fit and function for all aircrew. The frame was transitioned to DoD for a final decision on generalized purchase. The US Army and Navy, as well as international allies are expected to adopt this frame.

Recommendations were made for contact lens disinfecting system and types of lenses approved for aircrew use. A comprehensive review of refractive surgery, to include radial keratotomy (RK) and photorefractive keratectomy (PRK), was completed and delivered to AF/SG. Both of these procedures have significant negative factors that continue to preclude their use in USAF aircrew.

Several significant patents were awarded this year involving gamma camera technology and a 3-D eye tracking device. The eye-tracker technology is proposed as a future target-acquisition enhancement device. The gamma camera technology, capable of enhancing current imaging cameras, has obvious technology transfer potential. A formal CRDA concerning the gamma ray camera system has already been initiated with Millenium Technologies, Incorporated.

Congress tasked DoD scientific investigators to study the provision of primary and preventive health care services to military women. We developed an approved research protocol for the unique stressors of mixed-gender squadrons and female aviators in combat and deployment situations. Results will help line commanders improve unit effectiveness and mission safety in mixed-gender squadrons.

CHANGES FROM LAST YEAR

The Visual Electrodiagnostic Laboratory (VEL), the only such lab in DoD, completed the second phase of capability upgrades. Corneal topography was incorporated into the ACS evaluation process to provide a more sensitive assessment of corneal health.

Armstrong Laboratory placed the Laboratory for Aerospace Cardiovascular Research under the Physiology Research Branch broadening the scope of it's operationally relevant research. This research provides a clinical basis for development and application of the most effective procedures to protect aircrew from risk factors that may compromise their health, safety, and performance in Air Force Systems.

Development of an informatics system began last year. Initial work focused on a computerized aircrew physical examination database to interact with the on line physical examination system being developed by the Army and Navy. It will allow access and ready electronic link to all levels of the USAF aeromedical system.

The ACS Head Injury study expanded and joined the DoD/VA national multicenter head injury protocol. This will allow the Aerospace Neuropsychiatry Branch to develop prognostic criteria on individuals with a traumatic injury in a shorter time period.

MILESTONES

The Enhanced Flight Screening-Medical (EFS-M) testing for asymptomatic pilot applicants has been in operation since Spring FY 94. This highly cost-effective program screens out individuals who are likely to be referred to the Laboratory for specified cardiovascular disease, ocular motility disorders, or changes in the cornea that would be disqualifying and prevent a full flying career. In preparation for the start of EFS-M, over 200 echocardiograms performed on apparently normal subjects were reviewed. Results indicated that 25% of the normal subjects have mild regurgitation of mitral, tricuspid, or pulmonic valves. Using this data, standards were established for pilot trainees and proved to be highly predictive of the range of findings seen in the EFS population. These results will serve two purposes; to identify pilot candidates who may develop medical problems affecting flying status and to track the normal group and relate their medical histories to future medical conditions. Finally, work in psychological testing will provide information about the attributes of the successful aircrew as they relate to mission and weapons systems' specific requirements.

The study of incidentally discovered mitral valve prolapse is nearing completion. All records have been analyzed, follow-up questionnaires have been completed, and all echocardiographic studies have been reviewed to confirm the diagnosis using presently accepted criteria. Completion is expected in FY96.

Physiology researchers conducted multiple experiments designed to assess and enhance aircrew health, fitness and performance. These included clarifying physiological risks to combat performance associated with bedrest confinement and G-layoff. Results showed that participation in acute, intense physical exercise within 24 hours of return to flying status may eliminate the need for reconditioning flights.

Studies beginning in FY96 will target the visual performance of our aircrew members. A comprehensive analysis of the impact of various pathological eye diseases on NVG performance is planned. Two studies will focus on improved test procedures and enhanced sensitivity for common eye diseases, including glaucoma, in our aircrew. This work has potential application for the general population.

Research to identify accurate measures of color perception in aviators continues. This work is aimed at determining optimum color outputs on computer screens used in avionics. The data will allow us to plan optimum color environments for increased speed and accuracy in reading critical flight data. This research will benefit aircrew throughout NATO as the NATO AGARD Working Party 24 is specifically devoted to color vision issues in modern aircraft.

A new project was started to evaluate varying degrees of neutral-density filters for use in sun visors. The intent is to develop a less dark sunvisor made of color neutral material that aircrew will be more likely to use in operational engagements.

A comprehensive high $+G_z$ protocol was started in association with the Crew Technology Directorate. The goal is to evaluate ocular changes as a function

of exposure to high-G environments. The work was initiated in FY95.

Work in vestibular function testing lead to a fully operational Vestibular Test Battery (VTB) in FY95. Subsequent validation of the VTB will be accomplished in FY96. Concurrent engineering methods will permit active research and development to continue on the VTB during the validation phase. Technology transfer of the VTB technology via a CRDA with Neuro Kinetics Corporation. will be completed in FY97.

Research in the area of speech perception in noise continues. This work is attempting to identify when a hearing loss renders aircrew unable to perform the mission. Current waiver protocols require a costly in-flight hearing test. With the completion of this study, the Air Force will have a ground-based hearing test protocol that will be more cost effective, provide greater test validity, and have the potential for technology transfer into the civilian sector.

Two SBIR proposals will be started in the areas of otoacoustic emissions and auditory brainstem response measures respectively. The intent of this research is to revise available technologies to allow earlier, more reliable identification of hearing loss. This work, applied to the Air Force Hearing Conservation program, will provide cost savings and reduced occupational hazard from noise exposure.

To better protect aircrew health and safety several research studies measuring aircrew physiological responses in the high-G environment are underway. One study assesses the impact of restricted physical activity and reduced gravity on the body's ability to regulate blood pressure while a second determines the role of cardiovascular reflexes and risk of various dysrhythmias on cardiac performance during high-G exposure. Finally, we are trying to predict the health and fitness requirements necessary for successful combat task performance in high-G aircraft.

Experiments were conducted to understand the relationship between cardiovascular functions and vestibular responses. In the high-G environment this interaction could produce G-LOC. These experiments will be used to develop operational procedures to reduce the risk of mission failure.

MAJOR TECHNOLOGY THRUST 4: OCCUPATIONAL AND ENVIRONMENTAL HEALTH

USER NEEDS

- **Personnel Susceptibility to Directed Energy Systems**, (Air Combat Command, Air Force Special Operations Command, Air Force Surgeon General). This program determines human susceptibility to laser weapons for the purpose of developing laser eye protection. It also evaluates vulnerability of personnel to US systems, and emerging threats as well as possible countermeasures.
- **Active Denial Technology**, (Air Combat Command Mission Needs Statement, DEPSECDEF, Defense Nuclear Agency, USSTRATCOM). We are developing non-lethal technologies for the protection of high value assets, such as nuclear weapons.
- **Directed Energy Safety Standards**, (Air Force Surgeon General, Air Force Safety and Health Regulations, NATO Standardization Agreement, Systems Technical Needs). This is a continuous program to protect Air Force personnel and the environment from possible hazards associated with emerging Directed Energy technologies (e.g., ultrashort pulse lasers, ultrawideband radiofrequency systems).
- **Operational and Environmental Toxicology**, (Air Force Materiel Command; Air Force Surgeon General; Air Force, OSHA and EPA Regulations; Congressional Acts; Montreal Protocol). Mandated phaseout of ozone depleting chemicals (Halon and solvents in particular) drives current toxicology research for mission critical chemicals. Health effects and pharmacological research on chemicals which contaminate groundwater and soils assist in determining realistic remediation standards. Toxicology research and predictive toxicokinetic models improve risk assessments and cost-benefit analysis for new weapon systems.
- **Environmental Noise**, (Air Force Civil Engineer Mission Needs Statement, Air Combat Command, National Environmental Policy Act, Endangered Species Act). This research provides the development of tools for legally defensible environmental impact statements and environmental assessments to enable Air Force operations to execute as required.

GOALS

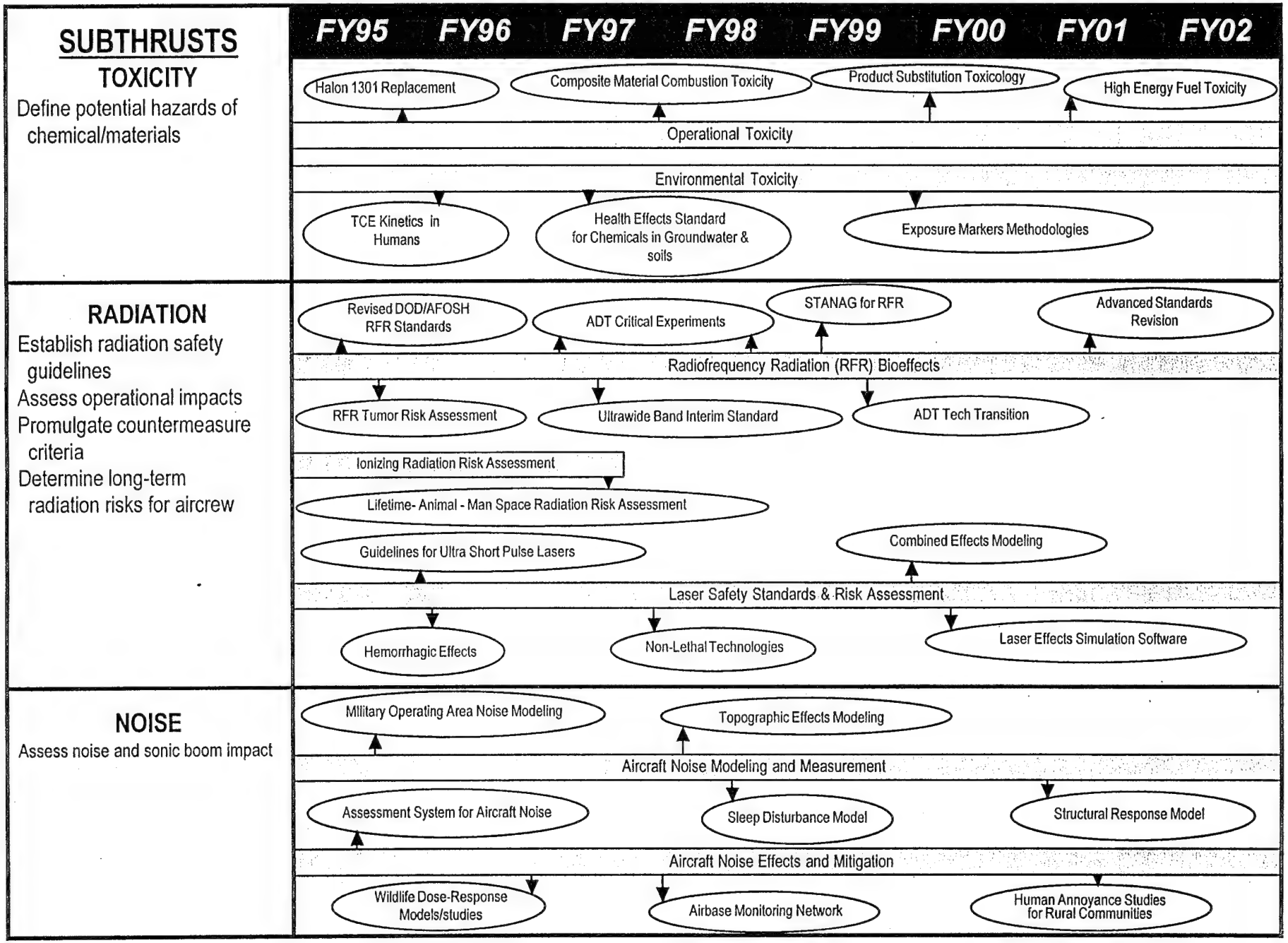
In order to meet our users' needs in Occupational and Environmental Health, the Armstrong Laboratory will:

- Develop laser eye protection equipment for aircrew and human exposure standards to permit operations and minimize casualties in current and projected laser threat environments.
- Provide biomedical data necessary to field the technology to deny human access to high-value assets making it available for transition to the Human Systems Program Office in FY97.
- Assess the effects of radiofrequency radiation to set realistic safety standards in day-to-day operations and protect personnel from future directed energy weapons and systems.
- Develop national standards and tools to assess compliance with guidelines for effects of aircraft noise on people and the environment providing the Air Force a legal defense against lawsuits and keeping training routes and military operating areas open
- Cut multi-billion dollar system life cycle costs up to six percent in FY2000+ by providing upfront materials safety and environmental assessments of potential toxicity.
- Provide a scientific basis for environmental remediation standards that will reduce base cleanup costs by millions of dollars.

MAJOR ACCOMPLISHMENTS

We completed Early Operational Assessment of two laser protection visors, the FV-7 Sun Visor and the FV-6MR Night Visor. We initiated a skin exposure limits study (jointly with the U.S. Army and

THRUST 4: OCCUPATIONAL AND ENVIRONMENTAL HEALTH



Russia) to provide important safety standards information on LANTIRN training lasers. The Advanced Aircrew Vision Protection Program (AAVP) is complete and has been made available to the Human Systems Program Office for transition. It is being considered as a "fast-track" engineering development project.

The development of an updated NATO Radiofrequency Radiation Standardization Agreement (STANAG) was greatly advanced during two multinational workshops. The draft STANAG was presented to NATO in Belgium in Feb. FY95. A new DoD Instruction 6055.11, "Exposure of Personnel to Radiofrequency Radiation" was prepared to match recent changes in the ANSI/IEEE standard, C95.1-FY91, and awaits approval by the Deputy Undersecretary of Defense for Environmental Security.

Electromagnetic radiation analysis research yielded a mathematical algorithm for defining the wide bandwidth microwave pulse response for two-dimensional biological models of arbitrary shape. This step is significant for both performing electromagnetic radiation risk analyses and developing a means to determine tissue responses under battlefield conditions.

Significant accomplishments achieved last year in the Environmental Noise Program included transitioning the Assessment System for Aircraft Noise (ASAN) to the Air Force Center for Environmental Excellence (AFCEE). This program is expected to reduce ACC's cost for completing Environmental Impact Analyses Process (EIAP) documents by $1 million per year when fully fielded. A three year study on the effects of aircraft noise on predator-prey relationships was completed. The results of this study will be added to ASAN to assess the impact of aircraft noise on the ecological balance of animal relationships.

There were several major accomplishments in FY95 resulting from the Tri-service Toxicology Research Program. We proposed emergency exposure guidelines for HCFC-123, a proposed replacement for Halon 1211 fire-extinguishing agent, to the National Academy of Sciences. Halon is identified as an ozone depleting chemical (ODC). Assuring safe use of HCFC-123 will assist in reducing damage and loss of life in aircraft fires while significantly reducing the use of ozone depleting substances. Toxicology parameters for selection of advanced streaming agent candidates were provided to the Halon replacement program managers in AFMC.

A coordinated effort by the Air Force, Army, Navy, Coast Guard, Federal Aviation Administration (FAA), oil companies, and chemical manufacturers to replace currently used Halon 1301 fire suppression systems, centered around toxicology issues. The Toxicology Division was solely responsible for the toxicology and risk assessment information that was used to select the initial list of Halon replacements and ultimately the replacement of choice. A candidate replacement chemical that was selected due to its firefighting properties was found to be unacceptable from a human health perspective. This discovery averted a programmatic decision that would have compromised occupational safety and cost the AF millions of dollars in excess life cycle costs.

Pivotal research concerning carcinogenicity from trichloroethylene (TCE) is underway in the Air Force toxicology laboratories. A research consortium addressing the toxicity of TCE, a groundwater contaminant of concern to the Air Force, became a reality. This group includes scientists from government, industry, and academia who are sharing information and progress.

New methods for quantitatively estimating the hazards from dermal exposures to chemicals in the workplace have been recommended to, and accepted by, OSHA. Use of these guidelines in the workplace will improve worker safety and avoid unnecessary engineering controls.

CHANGES FROM LAST YEAR

The acquisition of new sources permits the resumption of research into the potential bioeffects and health hazards of exposure to fast rise time, ultrawide band electromagnetic radiation. The research focuses on behavioral effects, cardiovascular function, cellular survival and teratologic potential. Based on limited experimental work on these pulses and the unique, complex nature of ultrawide band emissions, a conservative interim exposure limit was proposed. Extensive experimental research is being directed toward the development of a scientifically sound permanent exposure standard.

The continuing proliferation of lasers both in the wartime and peacetime operational environment puts

even greater demands on our research to understand the safe limits and operational constraints of lasers. We were appointed to a HQ USAF "Tiger Team" to fully review and make recommendations on this operational issue.

Under Project Reliance, the collocation of Army, Navy, and Air Force radiofrequency radiation bioeffects research programs at Brooks AFB, TX was completed in early FY95. This collocation has resulted in the largest, most expertly staffed, and best equipped laboratory in the world for electromagnetic radiation health and safety research. Currently, we are alleviating cramped research conditions by the construction of the Tri-Service Directed Energy Research Facility. Tri-Service research collaborations, coordinated through the Tri-Service Electromagnetic Radiation Panel (TERP) and the Joint Directors of Laboratories Technology Panel for Directed Energy Weapons (JDL-TPDEW), are beginning to be effective.

MILESTONES

Optical radiation research will establish damage thresholds for single pulses from picosecond and femtosecond laser systems in FY96, develop methods to verify and validate models of susceptibility for personnel delivering precision guided tactical laser weapons munitions in FY97 and quantify the human factors interactions of holographic laser protective spectacles in FY99.

The high-priority Active Denial Technology Program is on track. Armstrong Laboratory, in collaboration with Phillips Laboratory, is conducting a series of critical experiments this year and next. Additional customers for this technology have been recently identified from both the Department of Defense and other U.S. government agencies. Support for efforts to apply high intensity acoustics to delay or deny access to high value DoD assets is proceeding well and on schedule, with studies to validate estimates of security models underway through FY96.

To support development in the field of ultrawideband, fast rise time electromagnetic pulses a refined permissible exposure limit for humans will be provided in FY96. This will involve detailed anatomic propagation studies to identify areas in the body subject to excess energy disposition. Algorithms to define direct microwave scattering from full complex, three-dimensional objects will be available in FY97. A study of tissue acoustic response to wideband signals in FY97 will support updates to the safety standard. Algorithms for the full human body and specific organ calculations will be established in FY98. Wideband standard reassessment will be completed in FY00. Wideband pulse effects on cell adhesion will be reported in FY01.

In FY96, the Environmental Noise Program will test the mobile airbase noise monitoring network (NOISENET) for MAJCOM use in resolving environmental noise controversy or litigation. An updated version of NOISEMAP will be transitioned to AFCEE which will incorporate topography effects on noise propagation. A controlled experiment on human annoyance to impulsive noise will be completed for the U.S. Army. The military operating area noise model (MR NMAP) will be incorporated into the next version of ASAN and work with ACC will begin to develop an ASAN training course. Experiments on the reciprocity method for assessing structural damage from acoustic loading will be completed in FY97.

The Halon fire-fighting agent replacement program is one of the most significant efforts in the hazardous materials area. Wright Laboratory screens agent effectiveness for fire suppression then the Tri-Service Toxicology Center studies all potential extinguishants with expected low toxicity. The Center will determine safe exposure levels for several candidate compounds. Occupational risks for those agents intended for use in occupied facilities, such as command posts, will be estimated by FY97.

Developing superior weapon systems involves using materials not currently employed in routine industrial practice. Only a very small percentage of these compounds have completed characterizations of their health and safety impact. To accommodate an accelerated development process, the Tri-Service Toxicology Center is currently developing methods for rapidly predicting the toxicity of new materials and by FY96 will transition basic research for molecular structural activity predictions. By FY97 new materials will be screened in six weeks or less using novel techniques and models for classical endpoints such as cancer, reproduction or neurological changes. This methodology will be added to multi-attribute decision logic and expert system shells for demonstration of a safety and health engineering design tool by the year 2001 in a joint

program with materials scientists and human and environmental engineers. In parallel with these activities, characterizing materials which meet critical mission priorities will continue.

In order to reach the goal of reducing Air Force hazardous waste cleanup expenses, a study to determine the risks associated with the top ten compounds driving restoration costs will be completed by FY96. Compounding the complexity of the analysis are the issues of simultaneous exposure from mixtures, alternative routes of biological uptake, toxic metabolites and degradation products. In current practice, regulatory levels are set well below levels that experience says are safe. Future models must realistically reflect this experience and document known safe levels. Billions of dollars in clean up costs are at stake over the next twenty years. By FY98, validated hazardous waste risk methodology models incorporating these experiences will be delivered to support the DoD risk-based cleanup approach.

GLOSSARY

AAVP	Advanced Aircrew Vision Protection
ABDA/R	Aircraft Battle Damage Assessment/Repair
ACC	Air Combat Command
ACS	Aerospace Medicine Consultation Service
ADT	Active Denial Technology
AETC	Air Education and Training Command
AFCEE	Air Force Center for Environmental Excellence
AFOSR	Air Force Office of Scientific Research
AFSOC	Air Force Special Operations Command
AGARD	Advisory Group for Aerospace Research & Development
AGE	Aerospace Ground Support Equipment
AIA	Air Intelligence Agency
AL	Armstrong Laboratory
AMC	Air Mobility Command
ANC	Active Noise Cancellation
APT	Advanced Personnel Testing
ASAN	Assessment System for Aircraft Noise
ATAGS	Advanced Technology Anti-G Suit
CAD	Computer-Aided Design
CONUS	Continental United States
CRDA	Cooperative Research and Development Agreement
DOD	Department of Defense
DSS	Decision Support System
EFS-M	Enhanced Flight Screening-Medical
FATE	Female Acceleration Tolerance Enhancement
FCT	Foreign Comparative Testing
G-LOC	G-Induced Loss of Consciousness
HMT/D	Helmet-Mounted Tracker and Display
HP-MSOGS	High Performance-Molecular Sieve Oxygen Generation System
IETM	Interactive Electronic Technical Manual
IMDSPO	Integrated Maintenance Data System Program Office
IMIS	Integrated Maintenance Information System
IRAD	Independent Research and Development
ITS	Intelligent Tutoring System
JAST	Joint Advanced Strike Technology
JPATS	Joint Primary Aircraft Training System
MAJCOM	Major Command
MNS	Mission Needs Statement
MPT	Manpower, Personnel, and Training
NATO	North Atlantic Treaty Organization
NVG	Night Vision Goggles
PRK	Photorefractive Keratectomy
ORD	Operational Requirements Document
RK	Radial Keratotomy
R&D	Research and Development
S&T	Science and Technology
SBIR	Small Business Innovation Research
STANAG	Standardization Agreement
STIG	Space Technology Interdependency Group
STOW-E	Synthetic Theater of War in Europe
TAP	Technology Area Plan
TCE	Trichloroethylene
TestPAES	Test Planning, Analysis and Evaluation System
TMP	Technology Master Process
US	United States
USAF	United States Air Force
VCATS	Visually-Coupled Acquisition and Targeting System
VE	Virtual Environment
VEL	Visual Electrodiagnostic Laboratory
VT	Ventricular Tachycardia
VTB	Vestibular Test Battery
WAM	Workload Assessment Monitor
WPW	Wolff-Parkinson-White

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

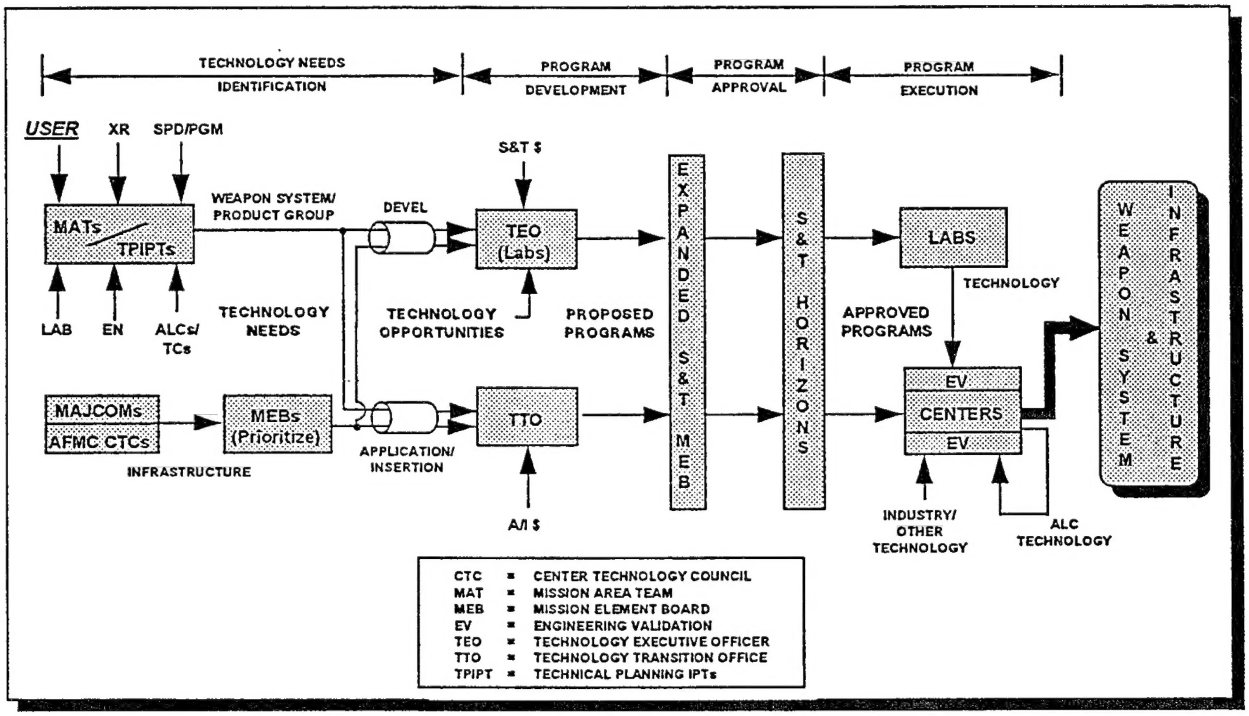


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification**--Collects customer-provided technology needs associated with both weapon systems/product groups (via TPIPTs) and supporting infrastructure (via CTCs), prioritizes those needs, and categorizes them according to the need to develop new technology or apply/insert emerging or existing

technology. Weapon system-related needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.

- Phase 2, **Program Development**--Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.
- Phase 3, **Program Approval**--Reviews the proposed project portfolio with the customer base via an Expanded S&T Mission Element Board and, later, the AFMC Corporate Board via S&T HORIZONs. The primary products of Phase 3 are recommended submissions to the POM/BES for S&T budget and for the various technology application/insertion program budgets.
- Phase 4, **Program Execution**--Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

TMP Implementation Status

The Technology Master Process is in its first full year of implementation. AFMC formally initiated this process at the beginning of FY94 following a detailed process development phase. During the FY95 cycle, AFMC will use the TMP to guide the selection of specific technology projects to be included in the Science and Technology FY98 POM and related President's Budgets.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STP, DSN 787-7850, (513) 257-7850.

INDEX